agriculture

MDPI

Article

# Beef Production in the Rangelands: A Comparative Assessment between Pastoralism and Large-Scale Ranching in Laikipia County, Kenya

**Veronica Mwangi [1,2,*], Samuel Owuor [1], Boniface Kiteme [2] and Markus Giger [3]**

[1] Department of Geography and Environmental Studies, University of Nairobi, P.O. Box 30197, 00100 Nairobi, Kenya; samowuor@uonbi.ac.ke
[2] Centre for Training and Integrated Research in ASAL Development, P.O. Box 144, 10400 Nanyuki, Kenya; b.kiteme@africaonline.co.ke
[3] Centre for Development and Environment (CDE), University of Bern, 3012 Bern, Switzerland; Markus.Giger@cde.unibe.ch
* Correspondence: verawambui@gmail.com

Received: 20 July 2020; Accepted: 28 August 2020; Published: 11 September 2020


**Abstract:** Beef production in Kenya is the forte of pastoralists and large-scale ranches in the Arid and Semi-Arid areas. Cross sectional data was collected from 67 pastoralists and seven large-scale ranches, selected through multistage stratified sampling. Comparative descriptive statistics, gross margin analysis and analysis of production constraints were done with the objective of assessing the pastoralists and large-scale ranches direct economic gains, constraints to production and potential for upgrading. Gross margin analysis showed that beef production is profitable for both pastoralists and large-scale ranches. However, large-scale ranches had much higher gross margins of up to six times more. There were significant differences in the live weight of cattle, prices and livestock selling channels and cost of production. Drought, livestock diseases, invasive plant species, lack of water and human-wildlife conflict were among factors limiting productivity of pastoralists. The difference in gross margins indicates existing potential for pastoralists to improve their earnings through a combination of product, process, and functional upgrading. Addressing key constraints to production can contribute to better gains and strengthen coexistence between pastoralists and large-scale ranches. Strategies and programmes to enhance cattle fattening, provision of livestock extension services, affordable feed inputs and collaboration between the two production systems should be considered in upgrading.

**Keywords:** pastoralists; constraints; large-ranches; gross margin

## 1. Introduction

More than ever before, food value chains are under pressure to produce more for a growing population with increasingly dynamic consumption patterns. As food demand steadily rises, production has not kept pace to ensure there is commensurate expansion in supply [1]. This has been the case for beef production in Kenya. Beef continues to be the most popular red meat in Kenya, constituting up to 80% of the red meat consumed in the country [2]. At an average increase of 13% in the last four years, annual beef consumption in Kenya is currently at 14 kg per person [3]. However, Bosire et al. [4] estimated a higher annual beef consumption of 17 kg per person.

The urban areas form the primary market for beef [5]. Past studies [4,6] have shown that per capita consumption of meat in urban Kenya is much higher than that of rural areas. Large cities such as Nairobi, itself a major destination and market for beef, have the highest per capita beef consumption of up to 25 kg [5]. Higher population growth, rising incomes and an expanding middle



source: https://doi.org/10.7892/boris.147614 | downloaded: 5.5.2023

class in the urban areas, have greatly contributed to a pronounced increase in beef consumption [7,8]. In addition, the urban markets are demanding high value meat and meat products pushed by the growing supermarket trend and expanding tourism [9]. These changing consumption dynamics present new market challenges as well as opportunities. Pressure remains on the supply side to close a possibly widening demand-supply gap. This situation not only provides a ready, wide, and possibly better urban market but also opportunity for adding value, creating employment and better incomes for beef producers.

The bulk of beef production takes place in the Arid and Semi-Arid (ASALs) counties of Kenya which host 70% of the country's livestock herd [10]. Laikipia County is one of the ASAL counties where beef production is a significant economic activity and a major source of household livelihood [11]. The county is an important supplier of livestock to the main slaughter complexes in the capital city of Nairobi [12]. Beef production in the ASAL counties of Kenya is carried out mainly by pastoralists and large-scale ranches. Pastoralists produce about 80% of the beef consumed in Kenya, while large-scale ranches produce another 2–5% and the remaining is produced by highland farmers as part of mixed farming [13]. Pastoralists and large-scale ranches differ markedly in terms of their strategies, mode of production and constraints [14].

Pastoralists are defined by their unique features of livestock mobility and communal management of resources [10]. Pastoralism is a low input and low output production system [15]. On the other hand, large-scale ranches are mainly defined by their commercial nature of production. They are also key in breeding pedigree steers and fattening of cattle targeted for the high end market [5]. Whereas pastoralists have remained the main producers of beef, their compositional (lean to fat ratio) and organoleptic (appearance, color, texture, and consistency) quality of beef has often been reported to be low [8,16]. This presents a major hurdle to the pastoralists because the urban market with its hospitality and service industries are increasingly demanding for high quality beef [7]. In addition, there is an emerging market of quality conscious butcheries [8]. This market niche has remained largely unfulfilled because, apart from large-scale ranches, there has been limited effort by pastoralists to improve their productivity [9,17].

The continued inability of pastoralists to meet the increasing and changing market demand has been associated with several factors which makes them vulnerable and livestock keeping a high risk economic activity. These factors include drought and erratic weather patterns affecting supply of feed and water, livestock diseases, poor management of pastures, lack of and/or weak delivery of extension and veterinary services, high cost of inputs, poor market infrastructure, low prices and insecurity [8,11,18,19]. These constraints not only limit the ability of pastoralists to meet changing market demands but also pose a threat to their livelihoods. In fact, pastoralists are among categories of producers that have the lowest development indicators [10]. Drought has particularly been a serious threat to both pastoralists and large-scale ranches due to its associated effects of constraining availability of two key production resources: water and pasture. Droughts, which were part of pastoralists livelihoods, are increasingly triggering crisis and conflicts [20]. Land use changes within Laikipia County since pre-colonial period have had the effect of restricting pastoralists within a small area and as such reducing the amount of land required for pastoralism [21]. Moreover, expanding crop cultivation and settlement of smallholder farmers from adjacent counties, privatization of land and administrative boundaries are limiting pastoralists' mobility and grazing alternatives [22,23]. As such, during drought, pastoralists in Laikipia County seek pasture in forests, open access patches and large-scale ranches, which is a recurrent source of conflict [14,18]. This poses a threat not only to the co-existence of the two production systems but also to the growth of the value chain.

The bulk of information on livestock comes from government and non-government reports at national level as well as major surveys and studies that are backed by the same institutions with a national approach. Most of these studies [5,6,9,12,16,19,24,25] sought to fill a knowledge gap and provide a general understanding of the livestock sector in Kenya which for a long period remained largely undocumented. There is lack of comprehensive local level data as well as local level knowledge

of the beef production chain. Moreover, with the devolved governance system that transferred the mandate of the agricultural sector from the national government to the county governments, data and information that is more context specific and of higher resolution is urgently needed to support decision making, policy formulation and design of effective interventions at the county level.

This study, therefore, endeavors to fill this gap by contributing to existing literature on beef production in Laikipia County through an assessment of the economic sustainability of beef production under the pastoralist and large-scale ranching production systems; and how well it is poised to respond to the current and future demands. The study set to achieve this by analyzing the direct economic gains of the pastoralists and large-scale ranches through a comparative gross margin analysis. In addition, the study established and compared constraints that hinder these producers from benefiting fully from their participation in beef production. The comparison between pastoralists and large-scale ranches highlights gaps in operational performance, identifies best practices for adoption, and points out areas for possible upgrading.

## 2. Materials and Methods

### *2.1. The Study Area*

The study was located in Laikipia, a semi-arid county of Kenya. Laikipia County covers an area of 9544 km$^2$, about 1.5% of Kenya's total area [26]. The county consists mainly of a plateau bordered by Mount Kenya, the Aberdare Ranges and the Great Rift Valley [27]. The county has varied climate corresponding to the change in gradient from the highlands in the south to the lowlands in the North. Annual rainfall varies between 750 mm in the south to 400 mm in the North while temperatures range between 16 °C and 26 °C [27]. Rainfall is mainly bimodal; the long rains, between March and June, and the short rains, between October and December [28]. Occasionally, there is a third rainy season in the months of June and July [22]. Rainfall in the rangelands, north of the county, is particularly highly unpredictable and increasingly variable [29]. Long rains are either short or absent, while short rains are absent in drought years. In wet years, both short and long rains are timely [22]. Altitude varies between 2600 m above sea level (masl) and 1500 masl [27]. The variation in rainfall and altitude is associated with changes in vegetation cover and land use activities. Vegetation cover varies from forest cover in the high altitude area in south, bordered by a belt of crop land, transitioning to a mix of bushland and grassland in the Laikipia plateau to the north [27]. Land tenure is strongly associated with different land use activities [29]. Crop farming, livestock keeping and tourism are the main economic activities in the county [30]. Livestock keeping is dominant in terms of land use and value [11]. More than 50% of the land is under livestock production, carried out primarily in two modes of production: large-scale ranching and pastoralism.

There are 48 large-scale ranches under private ownership and 13 group ranches owned by the pastoralists [28]. Figure 1 shows the study area and marks out the large-scale ranches and the group ranches that host the pastoralists in Laikipia. The large-scale ranches cover a total area of 3,824 km$^2$ (40% of Laikipia County) [27]. They are used for commercial livestock production but are also engaged in wildlife conservation and tourism. Large-scale ranches primarily rear the Kenyan Boran cattle and are important for breeding pedigree Boran steers which are known for high quality carcasses [2,5]. Large-scale ranches are reported to have a 10–12 hectare (ha) per Tropical Livestock Unit (TLU) preferred rate of grazing. On the other hand, pastoralists under the group ranches occupy a total area of 712 km$^2$ (7% of Laikipia County), where they practice communal grazing [28]. Some group ranches have wildlife conservancies and tourism enterprises. The group ranches are found in the drier northern Laikipia which is the least populated with a density of 17 persons per square kilometer (km$^2$) [27]. Recent statistics however, show a decline in population density to 14 persons per km$^2$ [31]. Average numbers of TLUs per pastoralists household in the group ranches are 18, with grazing land availability ranging between 2 and 4 ha/TLU [32]. Popular cattle breeds among the pastoralists include Zebu, Sahiwal and Boran [33]. A large proportion of the pastoralists herd comprise of female cattle,

kept for regeneration and milk production for local consumption; only one third of the marketed cattle constitute female [7,24].

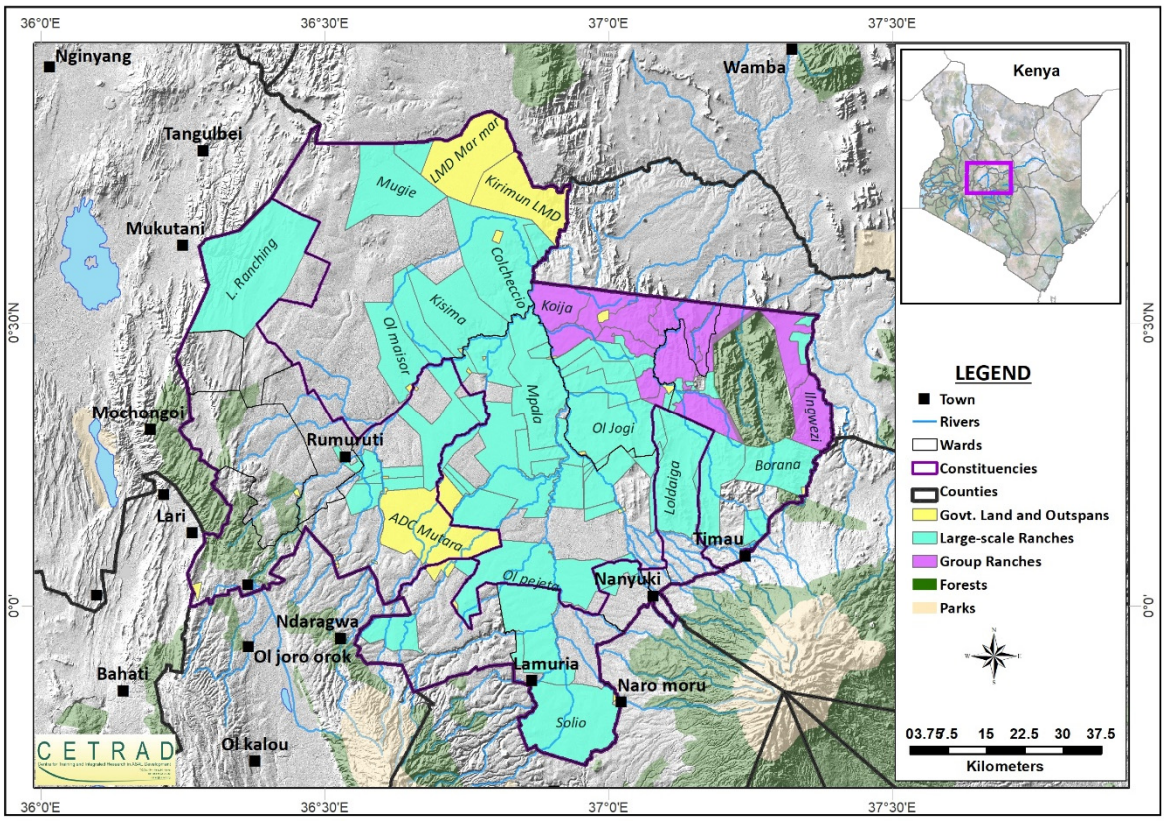


**Figure 1.** The Study Area. The sampled large-scale ranches bordered the group ranches that host the pastoralists. (Source: Centre for Training and Integrated Research in ASAL Development).

## 2.2. Sampling Procedure

The study sampled two types of beef producers: large-scale ranches and pastoralist households. The 48 large-scale ranches and 13 group ranches formed the sampling framework for the study. The study identified 10 large-scale ranches out of the total population of 48 large-scale ranches that bordered the group ranches. The choice was made to allow for study of association between the large-scale and group ranches as well as reduce spatial variations between the two. Out of the 10 large-scale ranches in the sample, seven were interviewed. The study randomly selected half (6) of the group ranches, which was considered representative, out of which 70 pastoralist households were sampled.

Key informants were used to estimate the total number of pastoralist households in the six selected group ranches. A list of 30 pastoralist households was generated from each of the six group ranches to form a sampling frame of 180 pastoralist households. After that, 40 pastoralist households were picked from four group ranches (10 each) with less than 300 pastoralist households while 30 pastoralist households were picked from two group ranches (15 each) with more than 300 pastoralists households. Three pastoralist household questionnaires were discarded during data analysis due to missing information. Hence, 67 pastoralist households were analyzed for the study.

## 2.3. Data Collection and Analysis

Cross sectional data was collected from the pastoralist households and large-scale ranches using a semi structured questionnaire. The questionnaire was administered face-to-face to increase the response rate. The questionnaire collected data on (1) production (number and type of livestock, costs, revenue, feeding); (2) marketing (sales channels, prices, volume of sales, markets, distance to markets);

and (3) farmer organization (membership to producer groups, relationships with other producers). Data on access to credit, training and extension services, constraints to production, and suggested solutions to production constraints were also collected.

The study carried out key informant interviews with government officials (District Livestock Officers, Area Veterinary Officers and Chiefs), group ranch leaders and elders. They provided more in-depth information on the study area, status of beef production, the linkages and relationships between pastoralists and large-scale ranches, pricing, markets, and challenges in beef production. Data collection took place from mid-May to mid-June 2017, a time when the area was experiencing drought. Data was cleaned by correcting or removing incorrect, incomplete, or inconsistent data. It was then coded and input into excel sheets. Data obtained from interviews was arranged into thematic areas such as markets, pricing, products, and constraints. Data analysis for gross margins was done using Excel and Stata 14 statistical software. We used the independent t-test to determine whether there was a statistically significant difference in the gross margins between the pastoralists and large-scale ranches. We tested the null hypothesis that the mean gross margins of pastoralists and large-scale ranches are the same. To achieve this, we used the Shapiro-Wilk test of normality to determine normality of variables and Levene's test for homogeneity of variances.

The economic gains from large-scale ranching and pastoralist production were assessed using gross margin analysis. The revenues and variable costs for each production system were estimated. The difference between variable costs and revenue gave the producers' gross margin. Mathematically, this can be represented by Equation (1):

$$GM_i = TR_i - VC_i \quad (1)$$

where $GM_i$ is the gross margin of beef producer $i$; $TR_i$ is revenue of beef producer $i$; and $VC_i$ is variable cost of beef producer $i$. Certain assumptions and use of proxy values were done in calculating variable costs and revenue for the pastoralists. This was necessitated by lack of pastoralist's recognition of certain costs, absence of production records and reliance on recall data. However, minimal assumptions were made in calculating variable costs of production for the large-scale ranches because they maintained a record of their input costs. Calculation of variable costs was derived from the cost of feeds and supplements, labor, routine spraying or dipping and veterinary services. Gross margins were obtained by subtracting variable costs from revenue, as such fixed costs such as stables and land were not considered for both pastoralists and large-scale ranches.

The cost of grazing for the pastoralists was calculated taking into account seasonality of pasture. Two scenarios of cost were calculated. First, where cost of pasture was considered available free of charge throughout the lifetime of the cattle. Second, where cost of pasture was incurred during the dry months when pastoralists experienced pasture deficit. Taking into consideration that the study area experiences 3–5 dry months and 7–9 wet months in a year, an average of 4 months was taken as the dry period during which pastoralists had to seek for alternative pasture. Large-scale ranches charged pastoralists a monthly fee of approximately USD 1.46 per head of cattle to access pasture during the dry months. Thus, we calculated the cost of pasture for the dry months with the monthly fee of USD 1.46 for four dry months and the total cost spread out in the 12 months of the year. Previous studies [8,33] have used grazing fees to calculate cost of feed. Although the fee is considered by pastoralists as payment for access of pasture and other services such as herding, dipping and salt licks, large-scale ranches consider it is a reciprocal fee. Large-scale ranches reported absence of measures to enforce payment of the grazing fee, hence in some instances, it went unpaid. Grazing agreements between the large-scale ranches and pastoralists allow pastoralists to graze some of their cattle in large-scale ranches under two circumstances: during dry periods and under cattle fattening programmes. Grazing agreements during the dry months served to reduce conflict, trespass and insecurity between pastoralists and large-scale ranches and was also viewed by large-scale ranches as a humanitarian measure in time of distress.

The cost of supplements was calculated using the cost given by the pastoralists, which was basically the cost of salt licks. Majority of the pastoralists engaged a family member to herd livestock, which they regarded as a contribution to the family's livelihood and not a cost of production. However, the study regards family labor as a cost and hence we calculated the opportunity cost of labor using the average wage paid by 40% of the pastoralist households that hired a herder. Cost of labor was not proportional to herd size. However, on average, a herder took care of 15 heads of cattle. Revenue was taken to be equivalent to the selling price of live cattle. Only the value of meat was considered. The migratory nature of pastoralists, made it difficult to account for possible revenue emanating from milk. The reasons for the focus on revenue from beef only are elaborated in the discussion section. Lastly, analysis of constraints in beef production for both pastoralists and large-scale ranches was undertaken to complement the analysis of gross margins. Pastoralists and large-scale ranches were asked to identify constraints they experience in beef production. They were also asked to suggest possible solutions to the constraints they had identified as well as suggest interventions that can assist to improve their participation in beef production.

## 3. Results

### *3.1. Characteristics of Pastoralists and Large-Scale Ranches*

A typical pastoralist's herd in the study area consists of cattle, sheep, and goats. However, due to the large size of herds, it was common for pastoralists to herd cattle separately from goats and sheep. In any case, cattle required more pasture and were usually moved far away from homesteads for grazing. Pastoralist households had an average TLU of 15 out of which cattle constituted 64% (Table 1). A tropical livestock unit is defined as an animal with a live weight of 250 kg [34]. We used conversion factors for TLU as recommended by FAO [34] and Nyariki and Amwata [35] as follows: camel, 1; cow or heifer, 0.7; steer, 0.8; sheep, 0.1 and goat, 0.1. The main breed of cattle kept by majority (73%) of the pastoralists was the Zebu. Female cows constituted a higher proportion (65%) of the pastoralists' cattle herd. The average pastoralist household size was six. Large-scale ranches had average TLU of 2015 out of which cattle constituted 95%. The stocking rates of large-scale ranches was 6.9 TLU/ha. Ownership of large tracts of land and the commercial nature of production enabled large-scale ranches to keep as many as 4500 TLU. Large-scale ranches kept a mix of cattle breeds, mainly Boran (58%).

**Table 1.** Average TLU and breeds of cattle for pastoralists and large-scale ranches.

| Parameter | Pastoralists ($n$ = 67) | Large-Scale Ranches ($n$ = 7) |
|---|---|---|
| TLU | | |
| Mean | 15.4 | 2015 |
| Min | 2 | 720 |
| Max | 82.4 | 4507 |
| Std. Deviation | 12.8 | 1195.9 |
| **Breeds of Cattle** | **(% of Households)** | **(% of Ranches)** |
| Zebu | 73 | 0 |
| Sahiwal | 4 | 14 |
| Boran | 0 | 58 |
| Aberdare Angus | 0 | 14 |
| Crossbreeds | 8 | 14 |
| Do not know | 15 | 0 |

### *3.2. Revenue, Costs and Gross Margins*

Table 2 presents selected descriptive parameters of both the pastoralists and large-scale ranches, largely in terms of their revenue, costs, and gross margins. Pastoralists sold an average of three heads of cattle per year. Majority (87%) sold their cattle through traders and brokers in designated livestock markets which took place fortnightly. Others (11%) sold through large-scale ranches under

cattle fattening programmes, while a smaller number (2%) sold directly to interested persons such as neighbors. Pastoralists trekked their livestock to the livestock markets on average 6 km away. Estimates from traders, veterinary officers, and officers at the slaughterhouses (key informants) gave the average live weight of pastoralists' cattle as 300 kg. Pastoralists did not weigh their cattle at the time of sale except those sold through large-scale ranches which were weighed before selling. None of the livestock markets sampled had a weighing scale. However, a few (15%) pastoralists estimated the live weight of their cattle at the time of sale at an average of 280 kg.

**Table 2.** Revenues, costs and gross margins for pastoralists and large-scale ranches.

| Parameter | Pastoralists | | | | Large-Scale Ranches | | | |
|---|---|---|---|---|---|---|---|---|
| | **Mean** | **Min** | **Max** | **Std. Dev.** | **Mean** | **Min** | **Max** | **Std. Dev.** |
| Average live weight at time of sale (kg) | 305 | 200 | 550 | 103.7 | 402 | 400 | 410 | 4.88 |
| Average age at time of sale (years) | 5 | 3 | 10 | 1.5 | 3 | 1.5 | 3.5 | 0.73 |
| Average price per kg—live weight (USD) | 0.8 | 0.49 | 1.6 | 0.26 | 1.62 | 1.46 | 1.94 | 0.17 |
| Number of cattle sold (per year) | 3 | 0 | 10 | 1.7 | 410 | 120 | 1000 | 359.8 |
| Average distance to the livestock market (km) | 6 | 2 | 12 | 2.8 | 0 | 0 | 0 | 0 |
| Carcass weight (kg) | 135–150 | | | | 200–240 | | | |
| Livestock selling channels | (as a % of households) | | | | (as a % of ranches) | | | |
| Trader/Broker | 87 | | | | 43 | | | |
| Large-scale ranches | 11 | | | | 0 | | | |
| Neighbors | 2 | | | | 0 | | | |
| Private businesses | 0 | | | | 57 | | | |
| Cost component (USD) | **Without Purchase of Pasture & (with Purchase of Pasture)** | | | | | | | |
| | **Mean** | **Min** | **Max** | **Std. Dev.** | **Mean** | **Min** | **Max** | **Std. Dev.** |
| Labor (per head, per month) | 2.06 * (2.06 *) | 1.62 (1.62) | 3.24 (3.25) | 0.23 (0.23) | 3.85 | 1.29 | 5.82 | 1.95 |
| Pasture (per head, per month) | 0 (0.49 **) | 0 (0.49) | 0 (0.49) | 0 (0) | 0 | 0 | 0 | 0 |
| Supplements, dipping/spraying and veterinary (per head, per month) | 0.66 (0.66) | 0 (0) | 2.93 (2.93) | 0.56 (0.56) | 2.56 | 0.86 | 3.88 | 1.30 |
| Total Cost (per head, per month) | 2.72 (3.20) | 2.06 (2.55) | 4.99 (5.48) | 0.57 (0.57) | 6.41 | 2.16 | 9.71 | 3.25 |
| Cost per head per year | 32.63 (38.45) | 24.74 (30.56) | 59.92 (65.75) | 6.87 (6.87) | 76.94 | 25.86 | 116.50 | 38.99 |
| Cost per head at sale (USD) *** | 163.13 (192.25) | 123.69 (152.82) | 299.61 (328.74) | 34.36 (34.36) | 230.83 | 77.59 | 349.51 | 116.99 |
| Revenue per head at sale (USD) | 255.16 (255.16) | 145.63 (145.63) | 485.44 (485.44) | 69.57 (69.57) | 653.18 | 648.54 | 664.76 | 7.91 |
| Gross margin per head | 92.03 (62.90) | −95.73 (−124.85) | 351.80 (322.67) | 81.09 (81.09) | 422.35 | 299.03 | 570.95 | 111.65 |

* Average rate of labor USD 30.92 per month, ** Total cost of pasture in 4 dry months spread out in 12 months, *** Total cost per head per year multiplied by age at sale (KES103 = 1USD at the time of the survey) Std. Dev. = Standard Deviation.

Pastoralists received an average price of USD 255 per head of cattle sold at the livestock market. The price was negotiated between the buyer (trader) and the seller (pastoralist). Price negotiations sometimes involved a broker. In most cases the price was determined by the buyer based on the physical appearance of the cattle in terms of its general body condition and estimated weight. Cattle sold at the livestock markets by pastoralists were on average five years old. Cattle sold through large-scale ranches under fattening programmes fetched as much as USD 680 per head of cattle.

On the other hand, large-scale ranches sold on average 410 heads of cattle annually, with some selling as many as 1000 heads of cattle per year. More than half (57%) of the large-scale ranches sold most of their cattle directly to processors, institutions, and retailers. Sale of cattle in large-scale ranches was dependent on market prices and season, with more cattle being sold during the dry season when there is less pasture. At the time of sale, usually three years, steers raised by large-scale ranches were well finished and weighed on average 400 kg. Such cattle resulted in high carcass weight and were most preferred by private processors. This category of cattle (steers) fetched an average price of

USD 1.62 per kilogram live weight, with some selling as high as USD 1.94 per kilogram live weight. Large-scale ranches also sold culled cows at a lower price of USD 1.17–1.55 per kilogram live weight because culled cows weighed less than steers.

The study estimates pastoralists cost of production at USD 2.72 per head of cattle per month for pastoralists who do not purchase pasture and USD 3.20 for those who purchase pasture during the dry months. A singe large-scale ranch can provide pasture for up to 2000 heads of cattle from the pastoralists during the dry months. Pastoralists who do not incur cost on pasture move their cattle far away from their neighborhoods, grazing in open accessible spaces, and do not necessarily graze in large-scale ranches during the dry season. However, as open spaces become limited due to increased land use and restriction of access, pastoralists are increasingly seeking pasture in large-scale ranches. Some pastoralists (28%) received relief feed from the government in the form of hay and dairy feed for a short duration (about a month) during the dry months. It was free of charge and not considered in the cost of feed. Labor cost for the pastoralists was USD 2.06 per head of cattle per month. More than half (60%) of the pastoral households engaged young family members (morans) to look after cattle. However, 40% of the pastoralists hired herders at an average monthly pay of USD 30.92.

Cost of production for the large-scale ranches was estimated at a monthly average of USD 6.40 per head of cattle. Labor constituted the largest cost component (60%) for the large-scale ranches, while supplements, dipping and veterinary services made up 40% of total cost. Large-scale ranches had ample pasture for their cattle throughout the year and only purchased supplements. The cost of production per head of cattle for the pastoralists who purchased pasture had a smaller difference to that of large-scale ranches, at the time of sale. This was because of the additional cost of pasture and the difference in average age of the cattle at the time of sale. Pastoralists took a longer time to sell (5 years) compared to large-scale ranches (3 years) hence continued incurring cost of production.

At an average selling price of USD 255.16 per head of cattle and a cost of production of USD 163.10 at the time of sale for pastoralists who did not purchase pasture and USD 192.25 for pastoralist who purchased pasture during the dry months, pastoralist earned a modest gross margin per head of USD 92.03 and USD 62.90 respectively, on sale of cattle. On the other hand, with a sale price of USD 1.62 per kg (live weight) and by which time the steers weighed about 400 kg, a large-scale ranch made a revenue of USD 653.18, returning a good margin of USD 422.35 on sale. This indicates that large-scale ranches obtained up to six times more gross margins per head of cattle than pastoralists.

The distribution of gross margins for both pastoralists and large-scale ranches were sufficiently normal for the purposes of conducting a t-test (i.e., Shapiro–Wilk test; $p = 0.06$ for pastoralists and $p = 0.33$ for large-scale ranches). In addition, the Levene test found that the assumption of homogeneity of variance was met: $F(1,72) = 2.95$, $p = 0.09$. Thus, a two-tailed independent t-test based on equal variances was carried out. There was a significant difference in the gross margins of pastoralists ($M = 92.03$, $SD = 81.09$) and large-scale ranches ($M = 422.35$, $SD = 111.65$); ($t(72) = 9.89$, $p = 0.000$). In other words, the difference between the two production systems is statistically significant in terms of their gross margins.

### *3.3. Constraints to Production*

The pastoralists identified four major constraints to beef production which are discussed in this section. These were drought, livestock diseases, invasion of pastureland by a plant invasive species (*Opuntia* spp.), and lack of water. Other constraints identified by at least 15% of the pastoralists included attacks of livestock by wildlife and insecurity. Majority (94%) of the pastoralists identified drought as the most pressing challenge in beef production (Table 3). Dry periods were perceived to be more frequent and extended, leaving pastoralists with little time to recover between such periods. The impact of drought was felt in terms of water and pasture scarcity. Less than one third (30%) of the pastoralists had lost livestock to drought. Rivers had dried up and 64% of the pastoralist households relied on a few boreholes and dams located up to 2 km away from homesteads for water.

**Table 3.** Constraints to production identified by pastoralists and large-scale ranches.

| Constraint | Pastoralists ($n$ = 67) | | Large-Scale Ranches ($n$ = 7) | |
|---|---|---|---|---|
| | ($n$) | (%) | ($n$) | (%) |
| Drought | 63 | 94 | 1 | 14 |
| Livestock diseases | 36 | 54 | 0 | 0 |
| Invasive plants | 28 | 42 | 0 | 0 |
| Lack of water | 17 | 25 | 0 | 0 |
| Wildlife attacks | 11 | 16 | 5 | 71 |
| Livestock raids | 10 | 15 | 0 | 0 |
| Low and fluctuating prices of livestock | 8 | 12 | 1 | 14 |
| Financial inability to buy livestock drugs | 5 | 7 | 0 | 0 |
| Unpredictable rainfall patterns | 3 | 4 | 0 | 0 |
| Lack of pasture | 3 | 4 | 0 | 0 |
| Invasion of pasture by pastoralists livestock | 0 | 0 | 4 | 57 |
| Lack of government support | 0 | 0 | 2 | 29 |
| Lack of good markets for well finished cattle | 0 | 0 | 1 | 14 |
| Unavailability of livestock drugs | 0 | 0 | 1 | 14 |

At least half (54%) of the pastoralists identified livestock diseases as a constraint to production. The issue of livestock diseases is complex. It involves interrelated problems of limited extension services, low coverage of animal vaccinations, transmission of diseases (through livestock interaction with wildlife), and high cost and unavailability of effective drugs. Less than half (46%) of the pastoralists lacked access to government vaccination despite annual provision of vaccines. Furthermore, half (54%) of the pastoralists lacked contact with government services, like extension or veterinary services. Government veterinary and livestock officers were few and covered an expansive area with limited resources. Private extension or veterinary service providers were near non-existent in the area. These service providers were located in towns, 50 km away. Pastoralists resorted to treating sick animals on their own with the possibility of making a misdiagnosis, administering an under dose or overdose of drugs.

Invasion of pastureland by *Opuntia*, a plant invasive species, was mentioned by 42% of the pastoralists. Efforts by the community to eliminate it had not succeeded. Pastoralists mentioned two main effects of the invasive plant. The first was suppression of grass growth due to its ability to propagate fast and survive in dry conditions. Second, the prickly hairs of its fruit lodged in animal's eyes and mouth causing blindness and difficulty in feeding. Lack of water was identified as a constraint to production by one quarter (25%) of the pastoralists. This problem is intertwined with drought. Being a semi-arid area, with an average annual rainfall of 400 mm, water is in short supply and the situation is exacerbated by drought.

Attack by wildlife was a concern for 16% of the pastoralists. Nine of the 13 group ranches are part of conservancies which advocate for wildlife protection. Six of the seven large-scale ranches engage in tourism activities and hence have conservancies. As such, wildlife roam freely in the conservancies and sometimes attack cattle. They also transmit ticks and diseases to cattle. Lastly, insecurity was a concern for 15% of the pastoralists. Livestock raids from neighboring pastoralists communities was viewed as a constant source of insecurity. Efforts by the government and community had not succeeded in completely resolving the problem.

The main concerns for the large-scale ranches were invasion by wildlife, invasion of pasture by livestock from the pastoralists and lack of government support (Table 3). According to the affected large-scale ranches, wildlife consumed grass meant for cattle, caused physical harm to cattle, and spread diseases and ticks to cattle. Invasion of pasture by livestock from the pastoralists occurred during the dry months when pasture became scarce in the group ranches. This was a common source of conflict between the two types of beef producers and a source of insecurity for the large-scale ranches. In addition, it affected the proper planning of pasture because large-scale ranches had to accommodate

unexpected and unplanned for herds of cattle. In some cases, it resulted in destruction of pastureland in the large-scale ranches through overgrazing. Lastly, the affected large-scale ranches complained about failure by the government to (1) put in measures to curb invasion of large-scale ranches by wildlife and pastoralists cattle; (2) provide effective vaccines and required livestock drugs; and (3) provide any form of incentive or support to boost beef production. Other concerns for large-scale ranches were lack of markets for well finished beef steers, low market prices and drought.

Table 4 provides a list of possible solutions suggested by the pastoralists and large-scale ranches to the constraints they identified. The main solutions, suggested by more than 10% of the pastoralists, include (1) interventions during drought through provision of feed and water to prevent loss of livestock; (2) removal of the invasive plant, as a possible solution to recovery of pasture; (3) improved access to vaccines and affordable livestock drugs; (4) water to be made more accessible, particularly during the dry season when seasonal rivers have dried up; and (5) good livestock and pasture management. Other possible solutions and interventions suggested by pastoralists included provision of security, increase in the number of livestock extension officers, more accessibility to pasture in the large-scale ranches, control of wildlife and livestock movement from neighboring counties, and improved markets and prices. On the other hand, the large-scale ranches proposed reduction of pastoralists' dependence on pasture in the large-scale ranches, restoration of a livestock marketing department, enhancement of the government veterinary department and control of wildlife.

**Table 4.** Solutions to constraints suggested by pastoralists and large-scale ranches.

| Suggested Solutions | Pastoralists ($n$ = 67) | | Large-scale Ranches ($n$ = 4) |
|---|---|---|---|
| | ($n$) | (%) | ($n$) |
| Interventions during drought | 31 | 46 | 0 |
| Elimination of invasive plant | 23 | 34 | 0 |
| Provision of vaccines and affordable livestock drugs | 20 | 30 | 0 |
| Availability of water through sinking boreholes, building dams | 17 | 25 | 0 |
| Livestock and pasture management | 15 | 22 | 0 |
| Provision of security | 6 | 9 | 0 |
| Provision of livestock extension and veterinary officers | 5 | 7 | 0 |
| Arrangements with large-scale ranches to provide pasture accessibility | 4 | 6 | 0 |
| Enclosure of wildlife | 4 | 6 | 1 |
| Control of animal movement to control diseases | 3 | 4 | 0 |
| Better markets and prices | 3 | 4 | 0 |
| Reduction of community dependency on large-scale ranches | 0 | 0 | 4 |
| Restore the livestock marketing department | 0 | 0 | 1 |
| Enhance the veterinary department | 0 | 0 | 1 |

## 4. Discussion

The assessment of beef production among the pastoralists and large-scale ranches brings out various features and differences in composition and size of livestock herd, size of land, marketing channels, weight, prices, and volume of sale. Findings on pastoralists herd size and composition are similar to Wanyoike et al. [8] who found that pastoralist households in five counties of North Eastern Kenya had on average a TLU of 16.1. Our analysis showing that pastoralists sold cattle in small quantities seemed to suggest reluctance to sell frequently. Sale of cattle seemed to coincide with the beginning of school terms during which the family expenditure rose sharply due to school fees necessitating sale of big stock. This is consistent with earlier studies by Bergevoet and Engelen [2], Barrett et al. [24] and Gamba [25] that observed pastoralists reluctance to sell their livestock even in times of drought, except when in need for money to meet family expenditures. In the absence of other assets, accumulation of livestock assets by pastoralists serves as a strategy to manage risks and shocks such as drought and the need for animal survival supersedes the necessity of keeping livestock in top-quality body condition [8,14]. Such a selling strategy has the possibility of leaving pastoralists vulnerable to opportunistic traders since the sudden need to sell may come at a time when the cattle are not in good body condition. This pattern of sale by pastoralists differed markedly from large-scale ranches who optimized their sales to maximize on profit. Large-scale ranches sold their cattle after

attaining specific weight and body conditions. In addition, they reduced their herd size to cope with drought by selling more to avert possible losses. Pastoralist on the other hand moved their livestock in search of pasture or paid to graze in large-scale ranches. These strategies help explain the volume and patterns of livestock sale among the pastoralists and large-scale ranches.

A study by FAO [15] showed that the pastoral system is naturally a low cost method of production provided that pasture is freely or cheaply available to the pastoralists. This is confirmed by the results of gross margin analysis which showed a reduction in gross margin per head of cattle with an increase in cost of pasture. This result suggests that a significant increase in cost of pasture would result in diminished margins. This also confirms an earlier finding by Kadigi et al. [36] that profit margins for beef producers are less if cattle are kept for longer periods. The cost of production for the pastoralists who purchased feed in the dry months were comparable to a previous study by Korir [33] that estimated the variable cost of rearing indigenous cattle at USD 3.52 per head per month.

The monthly cost of production for large-scale ranches was twice as much as that of pastoralists. This can be explained by difference in the cost of supplements and veterinary costs, which was higher for large-scale ranches. However, the difference in cost, at the time of sale for large-scale ranches and pastoralist who purchased feed, was less. This can be explained by the difference in age of cattle by the time of sale. Pastoralists sold their cattle while at least two years older compared to cattle from large-scale ranches thus incurring cost for the extra years. Despite pastoralists selling their cattle at a later age, they still weighed much lower and fetched a lower price compared to those sold by large-scale ranches. Weight was an important factor in defining the quality of cattle and hence price. We attribute low cattle weight among the pastoralists mainly to cattle feeding practices. Results showed that the major feed input for pastoralists was natural pasture yet a key challenge to production was access to sufficient pasture due to, among other reasons, drought. Results of the study showed that pastoralist cattle, under cattle fattening programmes in large-scale ranches, weighed much more and fetched higher prices underlining the importance of proper cattle feeding and access to pasture. In addition to weight, type of breed, marketing channel and practices were important factors in explaining the price differentials between the pastoralists and large-scale ranches. Pastoralists had a high preference for the Zebu cattle breed compared to the Boran breed that was mainly kept by large-scale ranches. Studies [5] have shown that the Boran breed is highly valued by consumers because of its high quality beef and thus fetches higher prices. Majority of the pastoralists sold their cattle to traders in the livestock markets, where cattle were not weighed and prices were established through negotiations. This informality at the livestock markets works to the disadvantage of the seller (pastoralist). On the other hand, large-scale ranches weighed their cattle and sold at an established price per kilogram live weight hence realizing the true market value.

Weight of cattle, prices, age of cattle at sale and costs are key in determining and understanding the difference in gross margin per head between the pastoralists and large-scale ranches. The estimates of age, price, and live weight of a mature indigenous breed of pastoralist in the studies by Wanyoike et al. [8] and Korir [33] compare well with the findings of this study. However, the estimated gross margins per head for pastoralists in this study differed from that of Korir [33] that were much lower (USD 27.57). The difference could be due to use of different prices and age at the time of sale in estimating gross margins per head. The ability of large-scale ranches to achieve up to six times more in gross margins points to handicaps on the part of pastoralist on one hand, while on the other, it points to existing potential for improvement.

Our results revealed striking differences in constraints to beef production between the pastoralists and large-scale ranches that could further explain the difference in gross margins. While drought was the leading concern for the pastoralists, it ranked low as a constraint for the large-scale ranches. Several reasons could explain this. First, the associated impacts of drought which included invasion of large-scale ranches for pasture by wildlife and cattle from the pastoralists were the main concerns and not drought per se. Second, large-scale ranches plan well in advance for the dry season and maintain livestock densities commensurate with their carrying capacity. Third, it could also point

to the advantage of having sufficient pasture through ownership of large tracts of land. Similarly, studies by Wanyoike et al. [8], Wade [14], Carabine and Simonet [18], and Makokha and Witwer [19] acknowledged drought as a serious threat to beef production.

Large-scale ranches mentioned lack of government support as a constraint yet this was not identified by the pastoralists. This is because large-scale ranches felt that the solution to their key issues of ranch invasion by wildlife and pastoralists lay with the government. While on the other hand, failure by pastoralist to identify lack of government support as a constraint, yet results on provision of government services support this, could point to a state in which pastoralists have learned to live without government support. Lastly, the different sets of solutions indicates that design of solutions to beef constraints should be specific to the two types of beef producers. The solutions should be in harmony to address constraints related to the relationship between the two production systems with a view of strengthening the relationships.

There are limitations in the study that need to be considered while interpreting the results. The study focused on the main product of the beef value chain which is beef. Other products such as milk (important for family consumption), were not considered in calculating revenue. This decision was taken for two main reasons. First, challenges in collecting information on possible sale of milk since the survey was undertaken during the dry months when most cattle had migrated and milk production was low from the few left behind and was primarily for household consumption. Secondly, earlier studies [7,22] have shown milk production capacity among pastoralists is generally very low, available at certain times of the year and is mainly for home consumption. Our interviews showed similar results. Nevertheless, our approach to not include milk production may lead to a certain (but limited) underestimation of the overall benefits of the pastoralists strategy for subsistence and food security and thus should be kept in mind when interpreting our results or proposing strategies to improve pastoralists beef production. Moreover, Allegretti et al. [37] had a similar approach that compared pastoralism and large-scale ranching based on the value of meat produced. In calculating the cost of production, we considered variable costs only. As such, fixed costs such as cost of stables were not taken into account. First, our focus was in estimating gross margins as opposed to net margins. Second, unlike large-scale ranches, pastoralists did not have stables but temporary barriers made of branches of a thorny plant. As such, for comparative purposes, the cost of stables for large-scale ranches was not considered. In addition, veterinary costs were not considered in the calculation of production costs for the pastoralist. Majority of the pastoralists reported not having access to veterinary services but instead administered livestock drugs on their own. The cost of supplements for the pastoralists constitutes salt licks, as reported by the pastoralists. Low use of purchased inputs such as drugs and artificial insemination has been reported among the pastoralists [38]. Furthermore, the migratory nature of pastoralists, climatic and infrastructural conditions makes it difficult to achieve full coverage of veterinary and vaccination services [15]. In fact, some pastoralist reported taking cattle for natural salt licks instead of purchasing the same. In calculating the pastoralists cost of production and revenue we relied on recall data. However, data on prices, sale and costs was triangulated and validated by key informants including veterinary officers, traders, and livestock marketing officers. Nevertheless, despite the data limitations, the analysis allowed for an objective assessment of the two beef production systems and provides locally based scientific evidence that can help in designing strategies and interventions for improving beef production.

## 5. Conclusions

Gross margin analysis has revealed revenues accruing to each type of beef producer and the extent to which they differ. This has illuminated differences in prices, weight, and marketing between the two production systems. In addition, analysis of constraints has revealed some of the reasons behind the differences in productivity and earnings between the pastoralists and large-scale ranches. At the same time, identification of constraints has brought out areas in which interventions can be targeted to achieve more impact. Generally, issues related to drought, rangeland management, government

services, marketing and wildlife need to be addressed for sustainable beef production. Assessment of pastoralists and large-scale ranches has revealed the potential for pastoralists to upgrade production and improve revenues hence building a case for more focus on pastoralists. Government and private partnerships need to be developed to enhance provision of veterinary and extension services and affordable feed inputs to avoid reliance on natural pasture. However, whereas pastoralists seem more challenged than large-scale ranches, it is equally important to address the concerns by large-scale ranches, through more collaboration with the government and pastoralist communities, to make organizational and network upgrading more feasible by strengthening the coexistence of the two production systems. Such coexistence has proved beneficial particularly in upgrading pastoralists' beef production thorough cattle fattening programmes which offer a viable growth path for the pastoralists.

Product upgrading is necessary for pastoralists' production to respond to the current and future market demands, particularly in terms of quality and consistency of supply. Programmes need to be created or enhanced to encourage pastoralists to set aside a certain number of cattle annually for fattening. This will not only ensure they supply the demands of the market but also improve their incomes. Pastoralists and large-scale ranches can also engage in process and functional upgrading through beef processing and cold chain distribution. This would open up capabilities of innovating products for niche markets locally as well as for the international market. The success of upgrading requires the support, investment, and coordination of all stakeholders, including beef producers, government, and non-government institutions. The government is an important enabler in upgrading beef production. Renewed efforts, serious commitment and investment is required to create a better production environment for both pastoralists and large-scale ranches.

**Author Contributions:** Conceptualization, V.M.; methodology, V.M.; formal analysis, V.M.; investigation, V.M.; writing—original draft preparation, V.M.; writing—review and editing, S.O., B.K., M.G.; supervision, S.O., B.K. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by the Swiss National Science Foundation (SNSF) through the Swiss Programme for Research on Global Issues for Development (r4d programme), grant number 400540_152033.

**Acknowledgments:** This research was facilitated by the Centre for Training and Integrated Research in ASAL Development (CETRAD). We thank Grace Wambugu, Paul Putunoi, Joseph Sintaroi, Fredrick Munyao, Patricia Mambo and Dennis Kithinji for the assistance accorded during data collection and cleaning. We are grateful to Elizah Peter who prepared the map for this study. We also thank two anonymous reviewers for their constructive criticisms and comments.

**Conflicts of Interest:** The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

## References

1. Foresight. *The Future of Food and Farming. Final Project Report*; The Government Office for Science: London, UK, 2011.
2. Bergevoet, R.H.M.; van Engelen, A. *The Kenyan Meat Sector; Opportunities for Dutch Agribusiness. LEI Report 2014-032*; LEI Wageningen UR (University & Research Centre): Wageningen, The Netherlands, 2014.
3. Kenya National Bureau of Statistics (KNBS). *Enhanced Food Balance Sheets for Kenya*; Kenya National Bureau of Statistics: Nairobi, Kenya, 2019.
4. Bosire, C.K.; Lannerstad, M.; de Leeuw, J.; Krol, M.S.; Ogutu, J.O.; Ochungo, P.A.; Hoekstra, A.Y. Urban consumption of meat and milk and its green and blue water footprints-patterns in the 1980s and 2000s for Nairobi, Kenya. *Sci. Total Environ.* **2017**, *579*, 786–796. [CrossRef] [PubMed]
5. Farmer, E.; Mbwika, J. *End Market Analysis of Kenyan Livestock and Meat: A Desk Study*; ACDI/VOCA: Washington, DC, USA, 2012.
6. Behnke, R.; Muthami, D. *The Contribution of Livestock to the Kenyan Economy*; IGAD LPI Working Paper 03-11; Inter-Governmental Authority on Development's Livestock Policy Initiative: Addis Ababa, Ethiopia, 2011.

7. Rakotoarisoa, M.; Massawe, S.; Mude, A.; Ouma, R.; Freeman, A.; Bahiigwa, G.; Karugia, J. *Investment Opportunities for Livestock in the North Eastern Province of Kenya: A Synthesis of Existing Knowledge*; ReSAKSS Working Paper No. 12; International Food Policy Research Institute (IFPRI): Washington, DC, USA, 2008.
8. Wanyoike, F.; Njiru, N.; Kutu, A.; Chuchu, S.; Wamwere-Njoroge, G.; Mtimet, N. *Analysis of Livestock and Fodder Value Chains in Arid and Semi-Arid Lands in Kenya*; International Livestock Research Institute (ILRI): Nairobi, Kenya, 2018.
9. Aklilu, Y.; Little, P.D.; Mahmoud, H.; McPeak, J. *Market Access and Trade Issues Affecting the Drylands in the Horn of Africa. Brief Prepared by a Technical Consortium Hosted by CGIAR in Partnership with the FAO Investment Centre*; Technical Consortium Brief 2; International Livestock Research Institute (ILRI): Nairobi, Kenya, 2013.
10. Government of Kenya. *Sessional Paper No. 8 of 2012 on National Policy for the Sustainable Development of Northern Kenya and Other Arid Lands*; Ministry of State for Development of Northern Kenya and Other Arid Lands, Government of Kenya: Nairobi, Kenya, 2012.
11. Government of Kenya. *Household Baseline Survey Report: Laikipia County*; Agricultural Sector Development Support Programme (ASDSP), Ministry of Agriculture, Livestock and Fisheries, Government Press: Nairobi, Kenya, 2014.
12. Muthee, A.M. *Kenya Livestock Sector Study: An Analysis of Pastoralist Livestock Products, Market Value Chains and Potential External Markets for Live Animals and Meat*; Deloitte Consulting Ltd.: Nairobi, Kenya, 2006.
13. Food and Agriculture Organization of the United Nations (FAO). *FAO Country Programming Framework for Kenya 2014-1*; FAO: Rome, Italy, 2014.
14. Wade, C. The Strategic Use of Private Property in a Rangelands Environment: The Political Ecology of Pastoralist Land Use Dynamics and Property Rights in Laikipia County, Kenya. Master's Thesis, McGill University, Montreal, QC, Canada, 2015.
15. Food and Agriculture Organization of the United Nations (FAO). *Livestock Production Systems Spotlight: Cattle and Poultry Sectors in Kenya*; FAO: Rome, Italy, 2018.
16. Alarcon, P.; Fèvre, E.M.; Murungi, M.K.; Muinde, P.; Akoko, J.; Dominguez-Salas, P.; Kiambi, S.; Ahmed, S.; Häsler, B.; Rushton, J. Mapping of beef, sheep and goat food systems in Nairobi—A framework for policy making and the identification of structural vulnerabilities and deficiencies. *Agric. Syst.* **2017**, *152*, 1–17. [CrossRef] [PubMed]
17. Pelrine, R.J. *Agricultural Value Chain Financing in Kenya: Assessment of Potential Opportunities for Growth*; A Report to the Kenya Value Chain Finance Centre by Inspired International; Financial Sector Deepening (FSD) Kenya: Nairobi, Kenya, 2009.
18. Carabine, E.; Simonet, C. *Value Chain Analysis for Resilience in Drylands (VC-ARID): Identification of Adaptation Options in Key Sectors*; VC-ARID Synthesis Report; Pathways to Resilience in Semi-Arid Economies (PRISE): London, UK, 2018.
19. Makokha, S.; Witwer, M. *Analysis of Incentives and Disincentives for Live Cattle in Kenya*; Technical Notes Series; Monitoring African Food and Agriculture Policies (MAFAP): Rome, Italy, 2013.
20. Fitzgibbon, C. *Economics of Resilience Study-Kenya Country Report*; Department for International Development (DFID): London, UK, 2012.
21. Kiteme, B.P.; Wiesmann, U.; Künzi, E.; Mathuva, J.M. A highland-lowland system under transitional pressure: A spatio-temporal analysis. *East. S. Afr. Geogr. J.* **1998**, *8*, 45–54.
22. Hauck, S.; Rubenstein, D.I. Pastoralist societies in flux: A conceptual framework analysis of herding and land use among the Mukugodo Maasai of Kenya. *Pastoralism* **2017**, *7*, 18. [CrossRef]
23. Boles, O.J.C.; Shoemaker, A.; Courtney Mustaphi, C.J.; Petek, N.; Ekblom, A.; Lane, P.J. Historical ecologies of pastoralist overgrazing in Kenya: Long-term perspectives on cause and effect. *Hum. Ecol.* **2019**, *47*, 419–434. [CrossRef]
24. Barrett, C.B.; McPeak, J.G.; Luseno, W.; Little, P.D.; Osterloh, S.M.; Mahmoud, H.; Gebru, G. Pastoralist livestock marketing behavior in Northern Kenya and Southern Ethiopia: An analysis of constraints limiting off-take rates. *SSRN J.* **2004**. [CrossRef]
25. Gamba, P. *Beef and Dairy Cattle Improvement Services: A Policy Perspective*; Tegemeo Working Paper 23/2006; Tegemeo Institute of Agricultural Policy and Development: Nairobi, Kenya, 2006.
26. Kenya National Bureau of Statistics (KNBS). *Statistical Abstract 2019*; Kenya National Bureau of Statistics (KNBS): Nairobi, Kenya, 2019.

27. Government of Kenya. *Laikipia County Integrated Development Plan 2018–2022*; Government of Kenya: Nairobi, Kenya, 2018.
28. Graham, M.D. *A Wildlife Conservation Strategy for Laikipia County (2012–2030)*, 1st ed.; Laikipia Wildlife Forum: Nanyuki, Kenya, 2012.
29. Letai, J. *Land Deals in Kenya: The genesis of land deals in Kenya and its implication on pastoral livelihoods—A case study of Laikipia district*; A report for Oxfam GB: Nairobi, Kenya, 2011.
30. African Women's Studies Centre (AWSC). *Food Security Research Findings and Recommendations: Laikipia County*; University of Nairobi Press: Nairobi, Kenya, 2014.
31. Kenya National Bureau of Statistics (KNBS). *2019 Kenya Population and Housing Census. Volume II: Distribution of Population by Administrative Units*; Kenya National Bureau of Statistics (KNBS): Nairobi, Kenya, 2019.
32. Kaye-Zwiebel, E.; King, E. Kenyan pastoralist societies in transition: Varying perceptions of the value of ecosystem services. *Ecol. Soc.* **2014**, *19*, 37. [CrossRef]
33. Korir, R. *Beef Value Chain Assessment for South-West Mau, Kenya*; Report prepared for Initiative for Sustainable Landscapes; Program of IDH, The Sustainable Trade Initiative: Utrecht, The Netherlands, 2016.
34. Food and Agriculture Organization of the United Nations (FAO). *Guidelines on Methods for Estimating Livestock Production and Productivity*; FAO: Rome, Italy, 2018.
35. Nyariki, D.M.; Amwata, D.A. The value of pastoralism in Kenya: Application of total economic value approach. *Pastoralism* **2019**, *9*, 9. [CrossRef]
36. Kadigi, R.M.J.; Kadigi, I.L.; Laswai, G.H.; Kashaigili, J.J. Value chain of indigenous cattle and beef products in Mwanza region, Tanzania: Market access, linkages and opportunities for upgrading. *Acad. J. Agric. Res.* **2013**, *1*, 145–155.
37. Allegretti, A.; Hesse, C.; Mohammed, E.Y.; Sitayo, E. Economic valuation of pastoral meat production system in Arusha region, Tanzania. *Afr. J. Econ. Rev.* **2016**, *4*, 262–278.
38. Agricultural Sector Development Support Programme (ASDSP). *Agricultural Sector Development Strategy 2010–2020*; ASDSP, Government of Kenya: Nairobi, Kenya, 2010.


© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).